~~19~~. (Amended) A method of sensing position of a diffusely scattering surface comprising:

illuminating the surface with coherent illumination in first and second input beams angled toward the surface forwardly and rearwardly, respectively, relative to surface motion;

a4

directing light diffusely scattered from the surface in [forward and] rearward and forward directions, respectively, relative to surface movement to a fringe detector; and

sensing position of a fringe pattern from the diffusely scattered light interfering at the fringe detector as an indication of position of the diffusely reflecting surface.

17

~~21~~. (Amended) A method as claimed in claim ~~20~~ 16 wherein the input beams illuminate and the fringe pattern is derived from a common spot of the diffusely scattering surface.

a5

REMARKS

Claims 1-4, 12-13, 19-21 and 24 were rejected under 35 U.S.C. § 102(b) as being anticipated by Gates et al. and the remaining claims were rejected under 35 U.S.C. § 103(a) as being unpatentable over Gates et al. in view of Monchalin. Those rejections are respectfully traversed, and reconsideration in view of the above amendments and following remarks is respectfully requested.

As discussed in the background of the application, typical position sensors using interferometry require that an optical element be placed on a surface which is illuminated with one or more beams from a common laser source. The present invention is directed to a system and method which avoids the need for such an optical element on the surface.

As also discussed in the background of the application, there have been limited attempts in the past to avoid the optical element on the surface by relying on light which is diffusely scattered from the surface. An interferometric approach

25

suggested by Hercher et al. is illustrated in Figure 2 of the application. That approach has not gained commercial acceptance, presumably because of its sensitivity to motion other than the lateral motion of interest.

The present invention presents an interferometric motion sensor which, like Hercher et al., requires no optical element on the illuminated surface and which overcomes the sensitivity to nonlateral motion and position such as roll and standoff distance along an axis normal to the surface. To applicants' knowledge, it is the first motion sensor relying on illumination of a diffusely scattering surface which has been incorporated into a successful product.

In accordance with the invention, and as illustrated in Figure 4, for example, two illuminating beams 1 and 2 illuminate the moving surface from respective forward and rearward directions. Light which is diffusely scattered from the surface in forward and rearward directions is received on a fringe detector 28. Movement of the surface is detected through movement of the fringe pattern at the detector. In the preferred reflective approach, the detected light is backscattered; that is, as illustrated in Figure 6, for example, the detected scattered light originating from each of the illuminating beams travels back toward the beam source. This approach maximizes sensitivity to lateral movement while minimizing sensitivity to movement of the surface in a direction normal to the surface. To minimize sensitivity to roll, the two beams illuminate a common spot of the diffusely scattering surface.

The Gates et al. patent is another example of a wide variety of interferometers which require an optical element on the illuminated surface, i.e., element Z_2. Through action of a zone plate Z_1, Gates et al. creates two incident beams 5a and 5b directed along a common axis 6 toward the surface. (Note that the two reference numerals 5a point to the outer rays of a common beam, not separate beams.) The wavefronts of the two beams have different curvatures such that beam 5a illuminates zone plate Z_2

at a substantially larger spot than does beam 5b. The two beams return along the incident axis and are reflected through another zone plate Z_3 for interference at a detector 14.

Although the operation of the Gates system is not clearly described, Applicants understanding of it is presented in the attached sketch, along with a copy of Figure 5 of the patent. That sketch can be compared to Figure 1 of Gates et al. with the optic axis unfolded at the zone plate Z_2. In addition, since a zone plate is a diffractive optical element which performs as a lens having multiple focal powers, the sketch replaces the zone plates with representations of refractive lenses. The portion of the sketch to the right of the zone plate Z_2 can be compared to Figure 5.

As shown in the sketch, and as described in Gates (column 3, lines 61-64), zone plate Z_1 "divides the beam into a transmitted beam 5a and a first order diffracted beam 5b." That is, Z_1 acts as an unpowered piece of glass to create 5a and as a positively powered lens to create 5b. Following Gates (column 4, lines 4-6), zone plate Z_2 similarly acts as a positively powered lens: "Z_2 acts in the same order of diffraction to reflect beams 10a and 10b...towards the beam splitter 9." That is, the first diffracted order of Z_2 is used to focus beams 5a and 5b into focused points S_2 and S_1 respectively in both Gates' figure 5 and the attached sketch. Finally, zone plate Z_3 acts as an unpowered piece of glass to transmit beam 10b and as a positively powered lens to create beam 11a, the two beams which interfere at the detector.

Confirmation that zone plate Z_2 is an imaging element is found in the existence in Figure 5 of focused spots S_1 and S_2, which are images of the source point P. As shown in the sketch, S_1 is the image of the source formed by the two "lenses," Z_1 and Z_2, while S_2 is the image of the source formed by "lens" Z_2 alone.

From the above discussion, it becomes clear that Gates et al. would become inoperable if the optical element Z_2 were replaced with a diffusely scattering surface. Accordingly, the

reference teaches nothing toward a position sensor which relies on interference of diffusely scattered light.

To further emphasize that the present invention is directed to a system which relies on the fringe pattern resulting from interference of diffusely scattered light, each of the claims has been amended to include that phrase.

Even if Gates et al. had utilized a diffusely scattering surface (which would have rendered their system inoperable), the reference would not teach the novel aspects of such a system which are claimed in the present application. In particular, the first and second incident beams of Gates et al. are not angled toward the surface "forwardly and rearwardly relative to surface motion." Beams 5a and 5b are both incident along a common axis, albeit slightly offset from the normal. As noted in the sentence bridging columns 3 and 4, the "beam axis 6 is offset from the normal to the zone plate Z_2 by an angle ϕ to reject the mirror reflections of the transmitted beam 5a and the first order defracted beam 5b." With the common axis 6, both beams are angled in the same direction, so even if one were to consider movement of the surface in a vertical direction as viewed in Figure 1, the two beams would be angled forwardly or rearwardly but not "forwardly and rearwardly" as required by the claims. To emphasize that the two beams are directed toward the surface from opposite directions, the claims have been amended to insert the previously implied term "respectively." Further, claims 1 and 19 have been amended to clarify that forwardly directed light which is scattered rearwardly, and vice versa, is directed to the fringe detector.

The various dependent claims relate to preferred implementations of the invention presented in the independent claims, and because that invention is not suggested by the prior art, the specific implementations are not suggested. In particular, with respect to claims 3, 13 and 21, the fringe pattern of Gates et al. cannot be said to be derived from a common spot illuminated by the input beams. For that to be the

case, it is necessary that the significant portion of the fringe pattern be generated from light diffusely scattered from a common area of the surface. In Gates et al., the surface is not diffusely scattering, and the beam 5b intersects with the beam 5a over only a small region of the optical element Z_2. The interference pattern is derived from a very substantial portion of the beam 5a which is beyond the spot defined by beam 5b.

With respect to the cited Monchalin reference, polarization is a well known tool in the field of optics. However, there is no suggestion of using that tool in the invention recited in the base claim. Similarly, sensor array fringe detectors are known in more conventional interferometers, but not with the claimed invention.

CONCLUSION

In view of the above amendments and remarks, it is believed that all claims are in condition for allowance, and it is respectfully requested that the application be passed to issue. If the Examiner feels that a telephone conference would expedite prosecution of this case, the Examiner is invited to call the undersigned at (781) 861-6240.

Respectfully submitted,

James M. Smith, Esq.
Attorney for Applicants
Registration No. 28,043
Telephone (781) 861-6240
Facsimile (781) 861-9540

Lexington, Massachusetts 02173
Dated: 11/12/98